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ABSTRACT

Cognitive conflict has been used as an effective teaching method since the 1980s, although the effects of this method are unclear. According to some researchers, cognitive conflict does not consistently lead to conceptual change. This paper describes a study investigating answers for the questions, What is the definition of cognitive conflict in learning?, and How it is aroused? and discusses the implications of the study in education. The study involved (n=4) 10th grade students in Korea. It is concluded that that cognitive conflict has four psychological constructs and is a perceptual state. (Contains 48 references.) (Author/YDS)

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WHAT DO WE KNOW ABOUT STUDENTS' COGNITIVE CONFLICT IN SCIENCE CLASSROOM: A THEORETICAL MODEL OF COGNITIVE CONFLICT PROCESS

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Cognitive conflicts have long been a part of psychological theories of cognitive change (Cantor, 1983). Despite many shifts of emphasis, the Piagetian account of development has always considered the concept of cognitive conflict, or the internal experience of opposing contractions, to be absolutely central in cognitive development. The concept figured in Piaget's earliest writings, and in Piaget (1985) it was developed into the equilibration model describing inner self-regulations (Roy & Howe, 1990).

Since 1980s, using cognitive conflict as teaching strategy has been very popular in science education research. A considerable number of researchers argued that cognitive conflict has an important/positive effect on conceptual change (Stavy & Berkovitz, 1980; Posner, Strike, Hewson, & Gertzog, 1982; Hewson & Hewson, 1984; Hashweh, 1986; Kwon, 1989, 1997; Thorley & Treagust, 1989; Niaz, 1995; Druyan, 1997; Lee, 1998).

However, there are still remained questions about the effect of cognitive conflict (Hewson, Beeth, & Thorley, 1998). Some researchers (Dreyfus, Jungwirth & Eliovitch, 1990; Elizabeth & Galloway, 1996; Dekkers & Thijs, 1998) argued that cognitive conflict strategies do not consistently lead to conceptual change. They said that even though students' ideas can be confronted with contradictory information through instruction, students frequently do not recognize conflict and sometimes the contradictory information can affect students negatively.

Vosniadou and Ioannides said that this dispute about the effect of cognitive conflict in learning science is not solved (1998, p.1214):

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> "Is cognitive conflict a good strategy to produce conceptual change?" In order to answer these questions we need further research on the development of knowledge about the physical world and about the learning science.

So, as Johnson & Johnson (1979) mentioned in the statements at the beginning of this paper, we still have similar problems. At this point, we should think about basic questions. " What is the definition of cognitive conflict in learning?" More generally, "What is cognitive conflict that is aroused in our students?" And "how is it aroused?" There are very few researchers who tried to answer these questions.

We believe that to understand the real effect of cognitive conflict in learning science, at first we should answer the basic questions. In this study, we tried to answer these questions, and we discussed the implication of our study in education.

The Definition of Cognitive Conflict

Damon and Killen (1982) said, "Cognitive conflict has never been precisely defined." And up to now there is no literature that explains the definition of it in detail. It is difficult to find the definition of cognitive conflict in any dictionary, either. Even in the cognitive conflict chapter of a book that deals with only conflict, there is no definition. On the whole, researchers used many terms together with cognitive conflict to explain cognitive conflict situation. There are many terms that were used with similar meanings to cognitive conflict by each researcher:

> cognitive dissonance (Murray, Ames, & Botvin, 1977; Botvin & Murray, 1975), cognitive gap (Furth 1981), conceptual conflict (Johnson & Johnson, 1979), discrepancy (Siegel, 1979, Zimmerman & Blom, 1983), disequilibrum (Damon & Killen, 1982; Murray, 1983; Murray, Ames, & Botvin, 1977), internal conflict (Bodlakova, 1988), paradoxes (Movshovitz-Hadar and Hadass, 1990), psychic conflict (Cntor, 1983), socio-cognitive conflict (Bearison, Sol Magzamen, & Filardo, 1986)

Each researcher used one or two words according considering that there is similarity or little difference among the meanings of those words. For example, Smedslund (1961) used the word

equilibration that was described by Piaget (1985). He suggested that equilibration may be similar to Festinger's cognitive dissonance or Heider's balance mechanisms.

Berlyne (1960) proposed the reason for using conceptual conflict instead of other words:

> Our own concern with conceptual conflict leads us in different directions from those pursued by Festinger (cognitive dissonance) and Abelson (cognitive imbalance). We are interested primarily in conflicts arising out of the denotative content rather than the affective tone of beliefs or thoughts and also in the relations between such conflicts and the pursuit of knowledge.

Hewson and Hewson (1984) used conceptual conflict rather than cognitive conflict because they intended to focus on conceptual problems in science learning. Like these examples, researchers chose a word according to their research concerns (for examples, conceptions, schema, function in cognitive development etc). Those are the reason why diverse words exist when explaining cognitive conflict situation.

In some literature, we could find few definitions of cognitive conflict as follows:

> Cognitive conflict is "awareness of a momentary disequilibrium" in the system of schemas (Mischel, 1971).
> In a social sense, cognitive conflict generally means some perceived contradiction between the subject's opinion and the opinions of others (Damon and Killen, 1982).
> Cognitive disequilibrium or conflict induced by awareness of contradictory discrepant information (Bodlakova, 1988).
> If a child eventually becomes aware of the fact that he holds two contradictory views about a situation and they both can not be true. This step is referred to as cognitive conflict or disequilibrium (Gredler, 1992).
> Cognitive conflict is created when one's expectations and predictions, based on one's current reasoning, are not conformed. It is disequilibrium (Wadsworth, 1996).
> Cognitive conflict is defined as a conflict between cognitive structure (i.e., an organized knowledge structure in the brain) and environment (i.e., a experiment, demonstration, peer's opinion, book, or something like that), or a conflict between conceptions in cognitive structure (Kwon, 1989).

As we can see, there are many words that have similar meaning to cognitive conflict. Each word has been used to explain a specific situation that is related to cognitive conflict because

cognitive conflict is a broad concept and not well defined. This might make researchers confused about using the word cognitive conflict.

After integrating the many words that have been used to explain and define diverse cognitive conflict, we defined cognitive conflict. Cognitive conflict is a perceptual state where one notices the discrepancy between one's cognitive structure and environment (external information), or between the components of one's cognitive structure (i.e., one's conceptions, beliefs, sub-structures and so on which are in cognitive structure). In this definition, cognitive structure means, as Langfield-Smith (1994) said, any mental representation used to organize knowledge, beliefs, values, or other data whether hypothetical or neurological.

Cognitive conflict is strongly related to cognition. This is the difference between cognitive conflict and general conflict because conflict is aroused by incompatible motives and needs noted in the following definition:

> Conflict is a perceptual state involving the executive function of the organism where the immediate choices in the organism's repertoire, together with the outcome of these choices, are seen to involve incompatible motives and needs (Parker and Archer, 1994, p. 665).

The Types of Cognitive Conflict

Many researchers described how cognitive conflict is aroused. For instance, Strauss (1972) presented two kinds of cognitive conflict (his word, disequilibrium). One is external, adaptational disequilibrium by means of prediction-outcome conflict. The other is internal, organizational disequilibrium through structural mixture conflict.

Siegel (1975) described three different kinds of cognitive conflict (his word, discrepancy): (a) internal cognitive conflict (between two competing ideas); (b) external social conflict (between two external events or sources of information); and (c) internal-external conflict (between an internal and external event).

Kwon (1989) presented three types of cognitive conflict. He thought Piagetian cognitive disequilibrium was a kind of cognitive conflict between one's cognitive structure and environment. Using Hashweh's (1986) analysis, Kwon also considered metacognitive conflict as other cognitive conflict that is a conflict between cognitive schemata. This cognitive conflict would be aroused when one might examine his/her own cognition without contacting his environment. Even in the Piagetian's disequilibria concept, there is the similar meaning to this kind of cognitive conflict; Hashweh made its concept clear.

In addition to these two kinds of cognitive conflicts, Kwon (1989) suggested the third kind of cognitive conflict. This kind of cognitive conflict can be aroused when a new conception, which might be scientific conception recently learned, is not compatible with an individual's past experience and/or the familiar with his/her old conceptions. Figure 1 shows Kwon's three kinds of cognitive conflict.

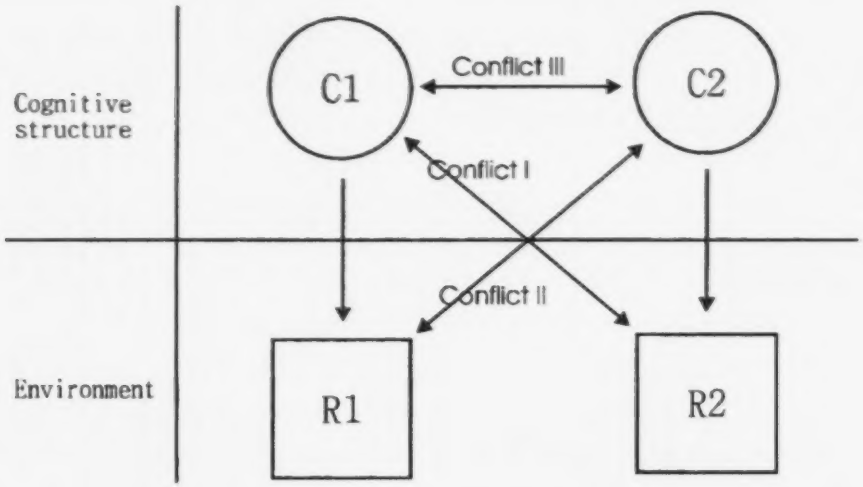

Figure 1. Kwon's cognitive conflicts model (Kwon, 1989)

This diagram is a modified version of Hashweh's original diagram (Hashweh, 1986). Kwon (1989) explained three kinds of cognitive conflict as follows:

> The upper part represents cognitive structure and lower part represents environment. For science instruction, a cognitive structure can be replace by scientific conceptions. C1 represents students' preconception or misconception. In a classroom situation it would be mostly a misconception. C2 represents a scientific conception to be learned. R1 represents environment that could be well explained by C1, while R2 is any environment explained only by C2. R1 and R2 do not represent only one single external phenomenon. It represents the whole bunch of observations and stimuli from one's environment.
> In this diagram, cognitive conflict by Piaget is conflict between C1 and R2 (Type I), cognitive conflict by Hashweh is a conflict between C1 and C2 (Type III). However, in the diagram one may easily recognize another kind of cognitive conflict between C2 and R1. Kwon proposed this as another kind of cognitive conflict (Type II). One may argue that this is just the Type I cognitive conflict. It may be correct, but for instructional purpose, to categorize this as a different conflict would be meaningful. Since Type I and Type II are all the cognitive conflicts between a cognitive structure and environment, the two cognitive conflicts could be categorized as the same kind. Under such a real situation as a teacher designs a new instruction, however, the two types of cognitive conflicts will function very differently in the preparation of instructional materials and in time allocation of activities. Therefore, to categorize the Type II as an independent type of cognitive conflict is meaningful.

When we think about the types of cognitive conflict, this diagram would be useful because of its simplicity. But from our interpretation of cognitive conflict, C1 and C2 should be not only pre/new conceptions which one learned in course of time but also beliefs, sub-structures, total structure, or something that is in cognitive structure, as we mentioned in the definition of cognitive conflict.

The Signs of Cognitive Conflict

Literature Review

Many researchers have tried to observe cognitive conflict and found diverse signs of it. For example, Miller (1944) observed hesitancy, tension, vacillation, and complete blocking in the cognitive conflict situation. Berlyne (1960) explained conceptual conflict had something like

these: doubt, perplexity, contradiction, conceptual incongruity, confusion, and irrelevance. Berlyne (1960, 1970) thought the children's degree of uncertainty (about anomalous information) as the major sign (indicator) of the degree of their cognitive conflict (his word, conceptual conflict). He measured cognitive conflict by subjective uncertainty (provided by the children themselves) and response latency. Smedslund (1961) found hesitation (reaction time), looking back and forth, uneasiness, and tension as children were in cognitive conflict situation. Zimmerman and Blom (1983) measured students' cognitive conflict by observing the degree of uncertainty, and response latency with using similar method to Berlyne's. Movshovitz-Hadar and Hadass (1990) found students' expressions in a state of a cognitive conflict from videotaped discussions. They said students showed expressions of curiosity arousal and expressions of an inner drive to resolve, as well as expressions of frustration, expressions of satisfaction with coping with inability to proceed, and expressions of contentment with feeling self-confident about a shaky state.

In summary, many researchers found many signs of cognitive conflict that could be observable and they used these signs as the indicators of the degree of cognitive conflict. According to these literatures, we could infer the psychological constructs of cognitive conflict. For instance, uncertainty, doubt, perplexity, contradiction, conceptual incongruity, irrelevance, being incredible are the signs of cognitive conflict when one recognizes anomaly that is contradict to one's expectation. So recognition of anomaly would be one construct of cognitive conflict. As another signs of cognitive conflict, to hesitate to response and/or to look back and forth are the behaviors when one tries not only to solve the conflict but also to decide to continue to do or not. In the one's internal state, one reappraises the conflict situation. So reappraising cognitive conflict situation is another construct of cognitive conflict.

Based on Anderson and Bourke (2000)'s affective area classification, we classified many affective signs of cognitive conflict into interest and anxiety. For instance, expressing curiosity arousal are the signs of cognitive conflict as a construct of it; interest. Tension, uneasiness, and frustration are the signs of cognitive conflict as a construct of it; anxiety. After all, there are four psychological constructs in cognitive conflict. Those are recognition of anomaly, reappraisal of cognitive conflict situation, interest, and anxiety.

Analyzing the Protocols of Previous Research

We analyzed protocols of the two previous research (Lee, 1990; Lee, 1998) where the researchers presented anomalous situations (i.e., demonstrations that were not incompatible with students' prediction) to students and observed their responses.

From these analyses, we found some verbal and nonverbal signs of cognitive conflict. According to the four constructs of cognitive conflict, we classified the signs as follows:

Recognition of Anomaly

When students recognized that their predictions were not consistent with the result of demonstration, they asked a question, wondered and muttered the result to themselves, or said the result was strange:

"Umm ... (rub one's chin).. Why does it?"
"Oh! It is same (height)."
(With a deep sigh) "it is strange."
"I cannot understand; it is strange"
(Looks the teacher with a amazing look)

Interest

After seeing the anomalous result, students expressed their interests by laughing or looked to be curious to know it:

(Laughs)
(A curious look)

Anxiety

In this case, we could find the verbal statements of students when they watched the anomalous result. They confessed it was difficult to solve the conflict problem by them.

> "Ah! I know nothing about it."
> "I fell into confusion."
> "Ah! I have a headache about that (problem)."
> "I cannot understand why the net force is zero. Even though it seems to be 2 N, I think the statement in the card is very like too. So I am troubled by the problem."

Reappraisal of Cognitive Conflict Situation (Hesitation to Response)

When students watched the anomalous result, many of them reserved their judgments that the problem was solved or not. A student did not move, and thought about the result for a long time. Another one looked at the experiment set closely and repeated thoughts.

> "I cannot explain the result well but...."
> "Centrifugal force? Inertial force? Centripetal force?" (With grumble to oneself, trying to understand the problem)

The Cognitive Conflict Process Model

The cognitive conflict process model was developed to explain the cognitive conflict when a student is confronted with an anomalous situation that is incompatible with his/her preconception in learning science. This model has three stages (see Figure 2): preliminary stage, conflict stage, and resolution stage.

The preliminary stage is the stage prior to cognitive conflict and includes the process of believing his/her preexisting conceptions and accepting anomalous situations as genuine (i.e., experimental results obtained by a teacher). In this model, cognitive conflict process is defined as after a learner (1) recognizes an anomalous situation, (2) expresses interest or anxiety in resolving the cognitive conflict, and (3) engages in cognitive reappraisal of the situation. For

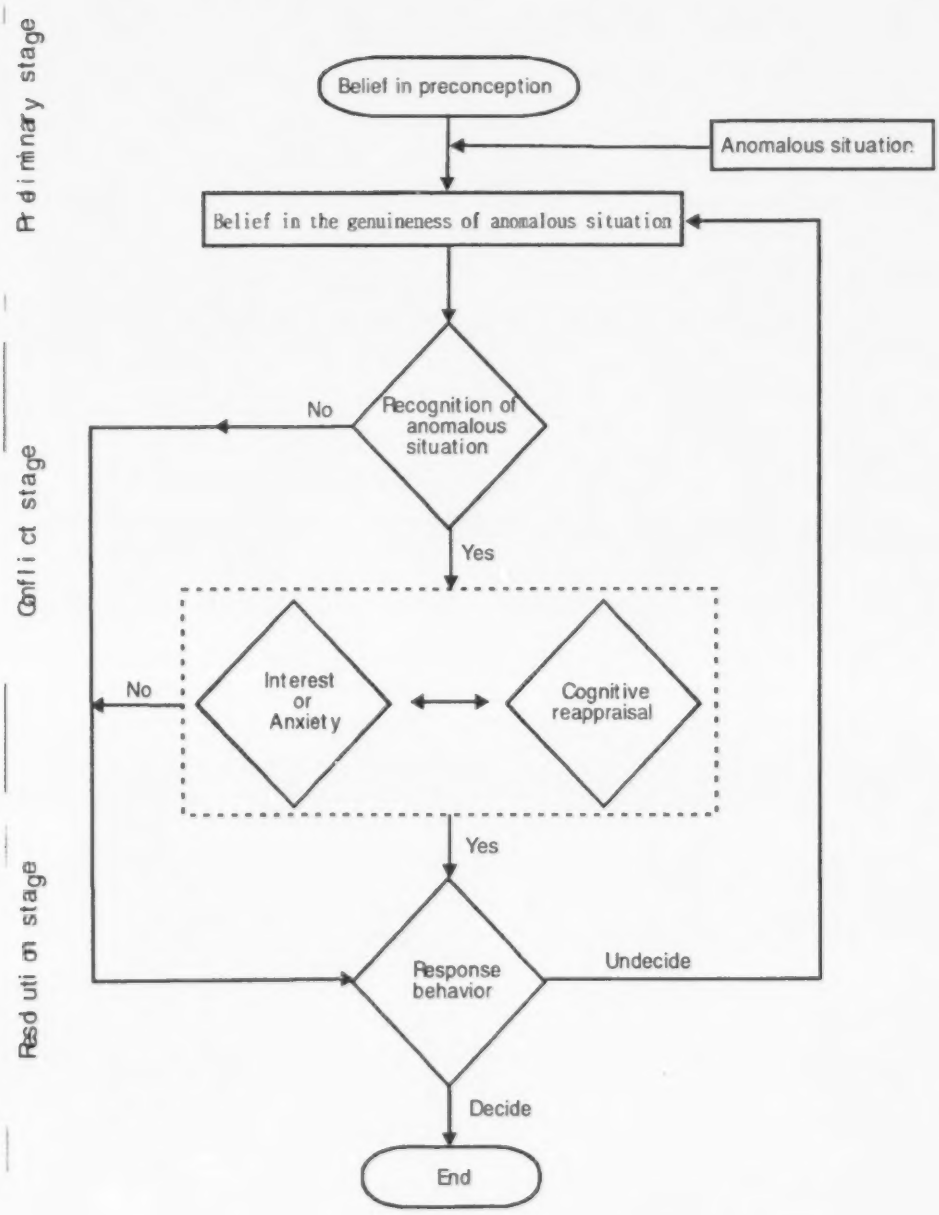

Figure 2. Cognitive conflict process model

instance, when a learner recognizes that a situation is incongruous with his or her conceptions, he or she should be interested in and/or anxious about this situation.

After these stages or simultaneously with these, he/she would reappraise his/her cognitive conflict situation in order to resolve it or just to quit it. In Movshovitz-Hadar and Hadass (1990), we found some examples of cognitive conflict process:

A student recognized anomaly and felt interest and anxiety simultaneously: (in a state of cognitive conflict) "It (the result of demonstration) is kind of a shock, it's fun… no…, it's…, mind stretching"

A student felt anxiety, but after reassessing his/her cognitive conflicts, he/she escaped cognitive conflict situation by solving the problem:

"I was threatened in the beginning and controlled it. Then I was able to start thinking and worked it out."

A student escaped his/her cognitive conflict situation by giving up to solve the problem:

"I was helpless. I could not wait to hear the solution."

This model supposes that four components of cognitive conflict are the psychological constructs of cognitive conflict: recognition of anomalous situation, interest, anxiety, and cognitive reappraisal. In terms of the components of cognitive conflict, we can understand why cognitive conflict has the potential for producing either highly constructive or highly destructive outcomes.

For example, if a student does not recognize the anomaly, ignores it, or he/she does not like to be in conflict state, then the cognitive conflict in this situation might be negligible. And if a student feels bad (like being frustrated or being threatened) instead of being interested, his/her cognitive conflict might be destructive one. Constructive cognitive conflict could be aroused

when a student recognizes anomaly clearly, experiences strong interest and/or appropriates anxiety, and reappraises cognitive conflict situation deeply. But if a student would not recognize the anomaly, ignore it, feel bad feeling (like frustration, being threatened) instead of interesting, and/or he or she would not like to be in conflict state, then the cognitive conflict in this situation might be negligible one or sometimes, destructive one.

In the resolution stage, a learner will try to resolve cognitive conflict in any way. The results of resolving this conflict will be expressed as an external response behavior. Response behaviors include those suggested by Chinn and Brewer (1998) such as ignoring, rejection, uncertainty, exclusion, abeyance, reinterpretation, peripheral theory change and theory change, and the knowledge-process activities suggested by Chann, Burtis and Bereiter (1997) such as sub-assimilation, direct assimilation, surface-constructive, implicit knowledge building and explicit knowledge building.

This model contains two assumptions: (1) the student's diverse characteristics (metacognition, learning motivation etc.) will affect the process of cognitive conflict. And (2) the components of the cognitive conflict will strongly affect the response behavior.

In our recent research (Kwon, Park, Kim, Lee, Lee, 2000), we investigated the relationship between cognitive conflict and students' response types. From students' interviews in this research, we found some examples of cognitive conflict process.

The participants were four students, tenth grade from high school in Korea. In the beginning of this research, we developed demonstration kits and preconception test on mechanics and electric circuit concept. Before the interview, four students were pretested on those concepts. Each student was individually interviewed. Based on the result of students' preconception tests, we presented the demonstrations that would be anomalous situations to each student. After this,

we asked them to express their thoughts and feelings about this situation. Then, we gave them the cards (see Figure 3) that express the main signs of cognitive conflict: recognition of anomaly, reappraisal of cognitive conflict situation (hesitation to response), interest, and anxiety. We asked them to arrange the cards according to the order they thought and felt them in the cognitive conflict situation and to say their other thoughts and feelings that are not expressed in the cards.

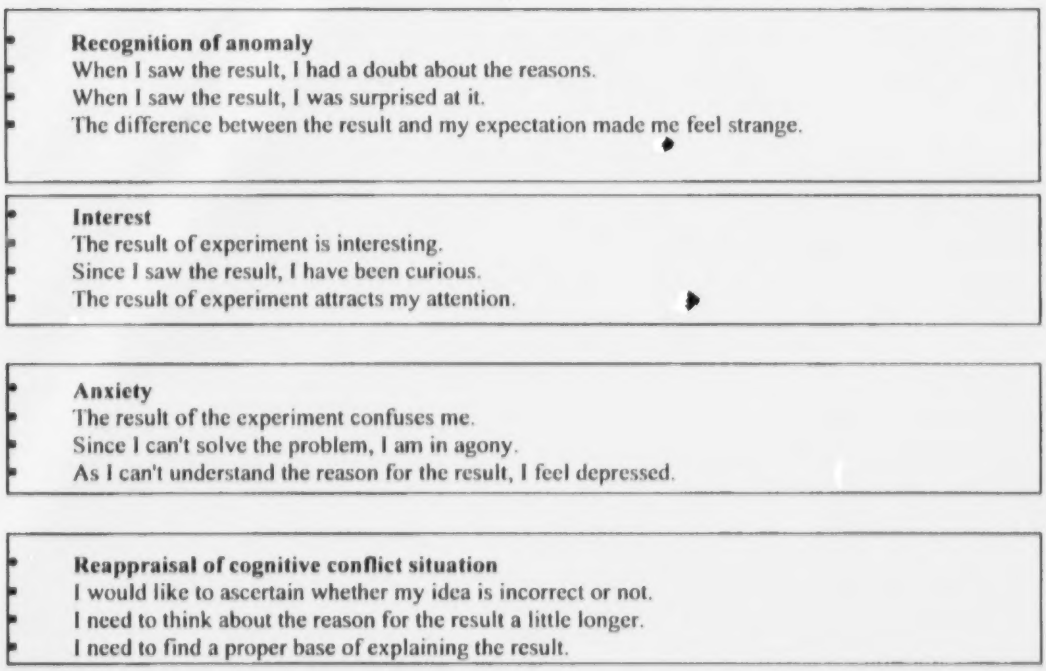
Recognition of anomaly
When I saw the result, I had a doubt about the reasons.
When I saw the result, I was surprised at it.
The difference between the result and my expectation made me feel strange.
Interest
The result of experiment is interesting.
Since I saw the result, I have been curious.
The result of experiment attracts my attention.
Anxiety
The result of the experiment confuses me.
Since I can't solve the problem, I am in agony.
As I can't understand the reason for the result, I feel depressed.
Reappraisal of cognitive conflict situation
I would like to ascertain whether my idea is incorrect or not.
I need to think about the reason for the result a little longer.
I need to find a proper base of explaining the result.

Figure 3. Four cards

The following excerpt illustrates the portion of the dialogue in the interview with student 1.

Interviewer: (presents a demonstration to student 1)
Student 1: (looks at the demonstration kit and the answer sheet by turning and thinking
for a while)
Interviewer: "Could you say now your feelings or thoughts?"
Student 1: "It is little short of a miracle, and I feel futility. I would like to know the
reason for the result."
Interviewer: "I made four cards which include some sort of feelings and thoughts about

this situation. Please arrange these cards, reflecting on your thoughts and
feelings that were experienced as time went by."
Student 1: (arranges the cards)
Interviewer: "Do you have any other feelings or thoughts about the result except these
(which were mentioned in the cards)?"
Student 1: "No."
Interviewer: "Do you think the result of this demonstration is right?"
Student 1: "Yes, because it is experimental result."
Interviewer: "Could you explain the result?"
Student 1: "I do not know. I saw the result for the first time."
(Talking to oneself) "Is it related with the principle of a lever?"

After watching the demonstration that was an anomalous situation to student 1, the students recognized the demonstration as an anomalous result. He felt futility as well as showed curiosity to know the reason. Until the end of the interview, he tried to resolve his cognitive conflict. In result, student 1 experienced cognitive conflict such as the process that was proposed in the cognitive conflict process model.

Conclusion and Implication

Based upon this study, the following conclusions and implications can be drawn:

- Cognitive conflict is a perceptual state where one notices the discrepancy between one's cognitive structure and environment (external information), or between the components of one's cognitive structure (i.e., one's conceptions, beliefs, sub-structures and so on which are in cognitive structure).
- There are four psychological constructs of cognitive conflict: recognition of anomaly, interest, anxiety, and reappraisal of cognitive conflict situation.
- Cognitive conflict has constructive, destructive, or meaningless potentials. This is strongly related to how students experience cognitive conflict. By checking the signs of cognitive conflict, we could see the potential of cognitive conflict.

- When a teacher tries to use anomalous phenomena to foster conceptual change, he/she could use the model of cognitive conflict process to anticipate how students might experience cognitive conflict. This could help teachers to let their students experience meaningful cognitive conflict.
- In the further research, the cognitive conflict process model should be tested more extensively. We should have enough evidences to answer the questions; when, where, about what, and how our students experience cognitive conflict.

- In addition, we should study how we can make the most of cognitive conflict in our classes. As Johnson and Johnson (1979) said, managing cognitive conflict is very important. However there is little strategy to manage cognitive conflict. Based on our study, further research could focus on the problem of managing cognitive conflict.

References

Anderson, L. W., & Bourke, S. F. (2000). *Assessing affective characteristics in the schools*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Bearison, D. J., Magzamen, S., & Filardo, E. K. (1986). Scio-conflict and cognitive growth in young children. *Merrill-Palmer Quarterly, 32*, 51-72.

Berlyne, D. E. (1960). *Conflict, arousal, and curiosity*. New York: McGraw-Hill.

Berlyne, D. E. (1970). Children's reasoning and thinking. In P. H. Mussen (Ed.), *Carmichael's manual of child psychology (Vol. 1)*. New York: Wiley, 3rd ed.

Bodrakova, W. V. (1988). *The role of external and cognitive conflict in children's conservation learning*. Doctorial dissertation, City University of New York.

Botwin, G., & Murray, F. (1975). The efficacy of peer modeling and social conflict in the acquisition of conservation. *Child Development, 46*, 796-799.

Chantor, G. N. (1983). Conflict, learning, and Piaget: comments on Zimmerman and Blom's "Toward an empirical test of the role of cognitive conflict in learning". *Developmental Review. 3*, 39-53.

Chann, C., Burtis, J., & Bereiter, C. (1997). Knowledge building as a mediator of conflict in conceotual change, *Cognition and Instruction, 15*, 1-40.

Chinn, C. A., & Brewer, W. F. (1993). The Role of Anomalous Data in Knowledge Acquisition: A Theoretical Framework and Implications for Science Instruction. *Review of Educational Research, 63*, 1-49.

Chinn, C. A., & Brewer, W. F. (1998). An empirical test of a taxanomy of responses to anomalous data in science. *Journal of Research in Science Teaching, 35*, 623_654.

Damon, W., & Killen, M. (1982). Peer interaction and the process of change in children's moral reasoning. *Merrill-Palmer Quarterly, 28*, 347-367.

Drekkers, P. J. J., & Thijj. G. D. (1998). Making productive use of students' initial conceptions in developing the concept of force. *Science Education, 82*, 31-51.

Dreyfus, A., Jungwirth, E., & Eliovitch, R. (1990), Applying the "cognitive conflict" strategy for conceptual change - some implications, difficulties, and problems. *Science education, 74*, 555-569.

Druyan, S. (1997). Effect of the Kinesthetic Conflict on Promoting Scientific Reasoning. *Journal of Research in Science Teaching, 34*, 1083-1099.

Elizabeth, L.L., & Galloway, D. (1996). Conceptual links between cognitive acceleration through science education and motivational style: A critique of Adey and Shayer. *International Journal of Science Education,* 18, 35-49.

Furth, H. G. (1981). *Piaget and Knowledge. Theoretical foundation*. Chicago: University of Chicago Press.

Glynn. S. M., & Muth. K. D. (1994). Reading and writing to learn science: achieving scientific literacy. *Journal of Research in Science Teaching, 31*, 1057-1073.

Gredler, D. E. (1992). *Learning and instruction: Theory into practice*. NY: Macmillan Publishing Company.

Hashweh (1986). Toward an Explanation of Conceptual Change, *European Journal of Science Education, 8*, 229-249.

Hewson, P. W., & Hewson, M. G. A. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science, 13*, 1-13.

Hewson, P. W., Beeth, M. E., & Thorley, N. R. (1998). Teaching for conceptual change. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (199-218). Kluwer Academic Publishers.

Johnson, D. W., & Johnson, R. T. (1979). Conflict in the classroom: Controversy and learning. *Review of Educational Research, 49,* 51-70.

Kwon, J. (1989). A cognitive model of conceptual change in science learning. *Physics Teaching (written in Korean) 7*, 1-9. Korean Physics Society.

Kwon, J. (1997). *The necessity of cognitive conflict strategy in science teaching*. .A paper presented at the International Conference on Science Education: Globalization of Science Education, May 26-30, 1997, Seoul, Korea.

Kwon, J., Park, H., Kim, J., Lee, Y. J., & Lee. G. (2000). *The analysis of the relationship cognitive conflict characteristics (levels and patterns) and response patterns of students confronted with anomalous situation in learning science*. Research Report on Subject Education RR98-VI-11, Ministry of Education in Korea.

Langfield-Smith, K. (1994). Cognitive map, In Ramachandran, V. S. (Eds.). *Human Behavior*. 647-653. NY. Academic Press.

Lee, G. (1990). *The response behavior of students who confronted with cognitive conflict situations.* Master dissertation, Korea National University of Education.

Lee, Y. J. (1998). *The effect of cognitive conflict on students' conceptual change in Physics.* Doctoral dissertation, Korea National University of Education.

Miller, N. E. (1944). Experimental studies of conflict. In Hunt, J. M. (Eds.), *Personality and the behavior disorders (Vol 1)*, NY: Ronald.

Mischel, T. (1971). Piaget: cognitive conflict and the motivation of thought. In Mischel, T. (Eds.), *Cognitive development and epistemology*. NY: Academic Press.

Movshovitz-Hadar, N., & Hadass, R. (1990). Preservice education of math teachers using paradoxes. *Educational Studies in Mathematics, 21*, 265-287.

Murray, F. B. (1983). Equilibration as cognitive conflict. *Developmental Review. 3*, 54-61.

Murray, F. B., Ames, G., & Botvin, G. (1977). The acquisition of conservation through cognitive dissonance. *Journal of Educational Psychology. 69*, 519-527.

Niaz, M. (1995). Cognitive Conflict as a Teaching Strategy in Solving Chemistry Problems: A Dialectic-Constructivist Perspective. *Journal of Research in Science Teaching, 32,* 959-970.

Parker, A., & Archer, T. (1994). Conflict Behavior, In Ramachandran, V. S. (Eds.). *Human Behavior.* 665. NY. Academic Press.

Piaget, J. (1985). *The equilibration of cognitive structure: the cental problem of intellectual development,* The University of Chicago Press, Chicago.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66,* 221-227.

Roy, A. W. N., & Howe, C. J. (1990). Effects of cognitive conflict, socio-cognitive conflict and imitation on children's socio-legal thinking, *European Journal of Social Psychology. 20*, 241-252.

Russell, J. (1982). Cognitive conflict, transmission, and justfication: Conservation attainment through dyadic interaction, *Journal of Genetic Psychology. 140*, 283-297.

Sigel, I. E. (1979). On becoming a thinker: A psychoeducational model. *Educational Psychologist. 14*, 70-78.

Smedsland, J. (1961). The acquisition of conservation of substance and weigh in children. *Scandanavian Journal of Psychology. 2*, 156-160.

Stavy, R., & Berkovitz, B. (1980). Cognitive conflict as a basis for teaching quantitative aspects of the concept of temperature. *Science Education, 64*, 679-692.

Strauss, S. (1972). Inducing cognitive development and learning: A review of short-term training experiments. *Cognition, 1*, 329-357.

Thorley, N. R., & Treagust, D. F. (1987). Conflict within dyadic interactions as a stimulant for conceptual change in Physics. *International Journal of Science Education, 9* (2), 203-216.

Vosniadou, S., & Ioannides, C. (1998). From conceptual development to science education: a psychological point of view. *International Journal of Science Education, 20*, 1213-1230.

Wadsworth, B. J. (1996). *Piaget's theory of cognitive and affective development*. N.Y. Longman.

Zimmerman, B. J., & Blom, D. E. (1983). Toward an empirical test of the role of cognitive conflict in learning. *Developmental Review. 3*, 18-38.

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